ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

Supplemental Report On

PROJECT NO. 14 - METHODS OF PROTECTION AGAINST FLASH BURNS

Subject: Time-Temperature Relationships which Produce Hot Air Burns of Human Skin

Project No. 14

20 July 1944

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

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710 SPMEA

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TIME-TEMPERATURE RELATIONSHIPS WHICH PRODUCE HOT AIR BURNS OF HUMAN SKIN

1. PROJECT: No. 14 - Methods of Protection Against Flash Burns - Supplemental Report on Time-temperature Relationships which Produce Hot Air Burns of Human Skin.

a. Authority - 1st Ind., Headquarters, Armored Command, 700.2/1 (20 Sept. 43) GNOHD to Letter 400.112/6 GNOML (25 Sept. 43).

b. Purpose - To obtain fundamental data useful in appraising the danger to crew members from fires in tanks.

2. DISCUSSION:

A flash burn may be produced by exposure of the skin to very hot gases even though the duration of contact is extremely short. Temperatures causing flash burns are estimated to be in the neighborhood of 1500°C with an exposure time of 0.01 seconds or less. Such flashes may be encountered in tanks. From available reports it seems that the initial flash is followed by a short period before general conflagration starts--if it does start. Once started, if not put under control, the tank fire increases the air temperature to values of 1000°F and above in a few seconds. In order to obtain a clearer understanding of the problem it seemed desirable to know the time-temperature relationship necessary to produce incipient and moderately severe burns from hot gases of temperatures under 1500°C. These data were obtained experimentally by a procedure described herein and are reported in graphic form in Fig. 1.

3. CONCLUSIONS:

a. The time-temperature relationship necessary for hot air, at temperatures between 100°C (212°F) and 500°C (932°F) to produce first or second degree burns on human forearms are as shown in Fig. 1. The time - temperature relationship for first degree burns may be expressed by the formula:

$$t = 0.1 \times 2.65^{\left(\frac{500 - T}{100}\right)}$$

where T = temperature °C of hot air, and t = time of exposure in seconds.

4. RECOMMENDATIONS:

Since the time required for first and second-degree burns within the

relatively low temperature range tested is quite short in comparison with observed tank evacuation times, continued vigilance must be maintained to protect tank crews by providing adequate fire-fighting equipment, by insisting on use of proper clothing, protective cream, and by ensuring adequate, easily-opened exits.

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3 Incls.
#1 - Appendix A
#2 - Appendix B
#3 - Fig. 1

APPENDIX A

1. TEST PROGRAM:

a. Twenty-five (25) soldier volunteers were selected for this study. The men included blonds, brunettes and red-heads, light-skinned and dark-skinned men, and men with and without large quantities of hair on their forearms. Their ages ranged from 18-32 years and averaged 25 years. Each subject was exposed to the heat source at a fixed temperature for five different lengths of time ranging from that which would give no burn to that which would give a second-degree burn (approximate burning times at each of five temperatures were pre-determined on rabbits and on the experimentors). The group was divided into five sub-groups--each one being tested at a different temperature. The final results include 25 burn exposures on five subjects at each of five different temperatures. The apparatus used is described in Appendix B. First-degree burns are defined as areas of hyperemia which persist for at least 24 hours and second-degree burns, those lesions consisting of hyperemia plus gross vesication apparent at 24 hours. The exposures were on the dorsal aspect of the forearm; three on the right and two on the left.

2. RESULTS:

a. The exposure temperatures were 100°C, 200°, 300°, 400°, and 500°C. At each temperature there was a minimum time of exposure below which no burn was produced. At the upper end of this time period, there is a short interval of exposure which will produce no burn but which will produce an initial hyperemia apparent within 15 minutes and of duration less than 24 hours. The time distribution of this phenomenon is shown in Chart 1. It is clearly a simple logarithmic function of time and temperature and shows little individual variation.

b. The time required to produce first-degree burns at any of these temperatures is only slightly longer than the erythema described above but shows considerably wider individual variation. Not only was there variation in the time required to burn at any given temperature but the size of burn varied among different individuals at a constant time of exposure. Hairiness appeared to give greater protection than depth of skin color. Light-skinned, non-hairy men burned more readily than either dark-skinned or pink-skinned red-heads. These variations however, appear to be too small to be of practical significance.

c. Second-degree burns showed even wider variations than first-degree burns but the pattern of susceptibility did not change appreciably. Pink-skinned men with little hair (red) appear to vesicate most easily. Blond hairless men rank second, blond hairy men third. Dark-skinned hairy men appear to be the least susceptible. These variations also are probably of little practical importance.

d. Third-degree burns (charring) were not studied.

Incl. #1

e. Temperatures above 560°C (approx. 1000°F) were not studied because exposure times of less than 0.06 seconds are required to burn. This is less than the best of human reaction times for all movements except the eye-lids (0.05 sec.) and exposures to such temperatures will always burn unprotected skin before the exposed part can be withdrawn.

Incl. #1

APPENDIX B

Hot air burns were produced at controlled temperatures and for controlled short periods of time. The air used to produce the burns was heated in a Fisher superheater--a bronze casting 6" x 2-3/4" x 3/4". Heat was supplied and controlled by two gas-air burners, one above and the other below the superheater. By adjusting the burners it was possible to maintain any desired temperature within a range of 100°C to 500°C. The flow of the air passed through the superheater was maintained at 6 liters per minute. Preliminary trials showed that at this rate a maximum temperature was obtained with a given amount of heat. The outlet tube of the superheater was 1 cm. in diameter and was partially projected through a 1½" diameter hole in a double transite wall mounted on the edge of a table. A sliding shutter mounted between the transite walls was attached to an electric timer. The shutter had an oblong hole in it that could be pulled rapidly or slowly across the hole in the double wall, thus allowing the hot air to pass through and strike the arm of the subject held against the wall. The shutter-timer assembly would record accurately the time of exposure to within 0.01 second. The temperature of the air was measured by an iron-constantan thermocouple and potentiometer at the point at which the air would hit the skin on the subject.

Incl #2

TIME — TEMPERATURE RELATIONSHIPS WHICH PRODUCE HOT AIR BURNS ON HUMAN SKIN

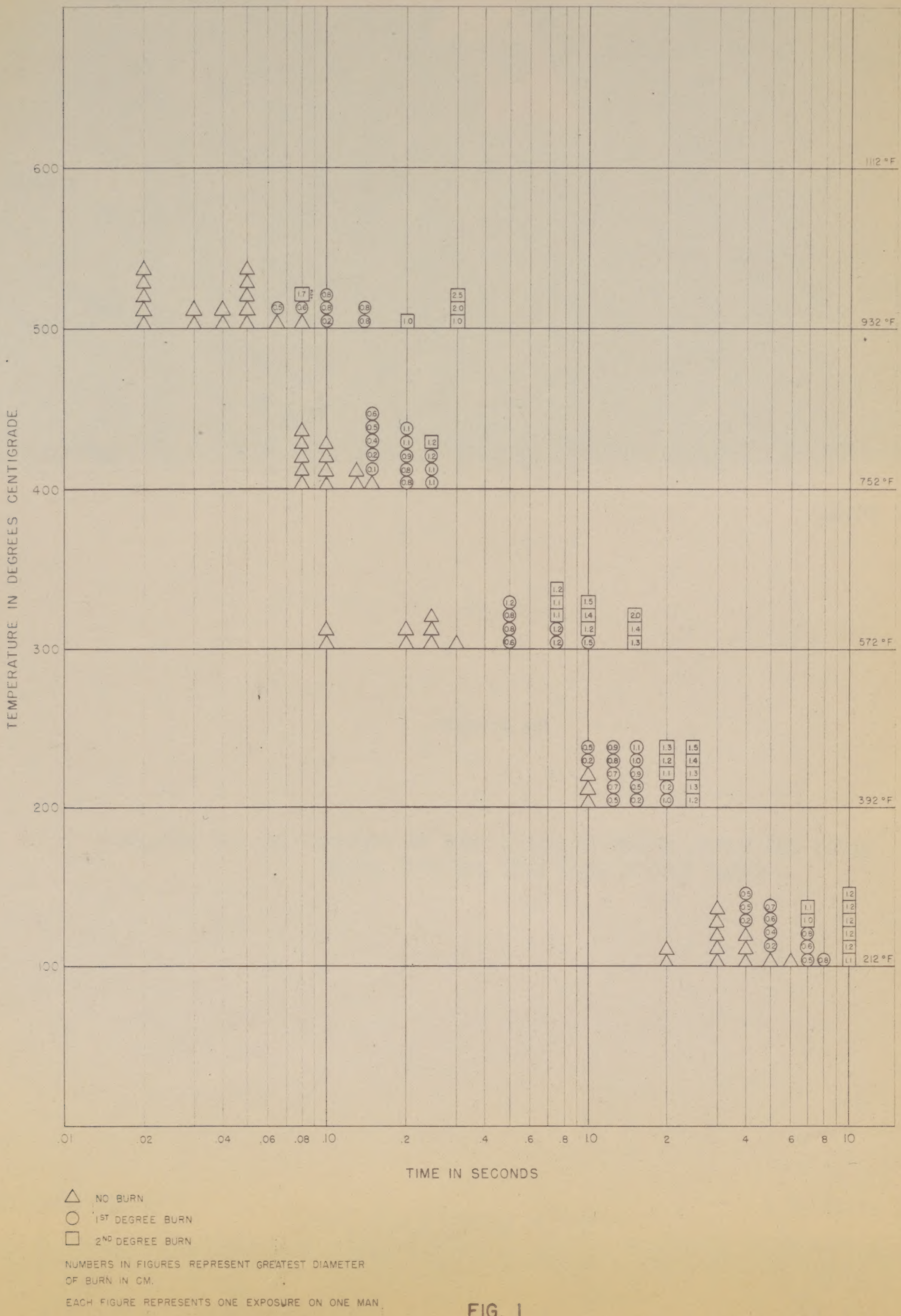

FIG. 1